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PLANNED PROGRAM

FOR

IMAGE ANALYSIS RESEARCH (U)

October 1966 through April 1967

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PLANNED PROGRAM
FOR
IMAGE ANALYSIS RESEARCH (U)

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LIST OF ILLUSTRATIONS

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TASK 2A OPTICS

2AA. THEORETICAL STUDIES

The following theoretical program involves the solution of partially coherent imaging problems of increasing complexity to provide guidance for the experimental program described under Part AB of this task. We shall:

1. Convert the format of the existing computer program (which calculates the intensity distribution in the image of quasi-monochromatic partially coherent objects) from IBM 7094 to IBM 360 to permit use of the expanded storage capacity of the 360 machine. This program will be written to accept quasi-monochromatic partially coherent illumination distributions and object distributions of arbitrary functional form. It will also accept impulse response distributions characteristic of ideal diffraction-limited or aberrated lenses.

2. Investigate analytical solutions of the following partially coherent imaging problems to guide computer calculations and to provide more physical insight than can be gained by direct computer calculation. Assuming partially coherent quasi-monochromatic illumination arising from an ideal incoherent source, we shall investigate the relation between object and image intensity distributions for an ideal lens and the following classes of objects:

   a. Sine waves

   b. Edges

   c. Square waves

   d. Three-bar targets.

We shall consider these objects in the following forms:

   a. Pure amplitude variations

   b. Pure phase variations

   c. Both amplitude and phase variations.

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3. Use the computer program written under item 1 above to calculate the intensity distribution in the image of the following objects, assuming partially coherent quasi-monochromatic illumination and an ideal lens:

a. Sine waves

b. Edges

c. Square waves

d. Three-bar targets.

We shall calculate the intensity distribution for these objects in the following forms:

a. Pure amplitude variations

b. Pure phase variations

c. Both amplitude and phase variations.

4. Compare and evaluate the results of items 2 and 3 above to determine the necessity for further analytical or computer calculations.

5. Extend the computer program written under item 1 to accept polychromatic partially coherent illumination distributions.

6. Determine the effect of spectral width and lens aberrations on the image intensity distribution in partially coherent imaging problems, assuming ideal incoherent sources, for objects selected from the classes described in items 2 and 3 above. The particular objects treated in this item will be chosen on the basis of the results of items 2, 3, and 4 above.

7. Evaluate the results of the quasi-monochromatic imaging studies conducted in items 2, 3, and 4 above.

8. Evaluate the results of the polychromatic imaging studies conducted in item 6 above.

9. Compare and assess the results of items 7 and 8 above to determine to what extent the illumination from polychromatic sources can be represented by the quasi-monochromatic approximation. Determine, on the basis of this comparison, what further studies are necessary using quasi-monochromatic or polychromatic sources.

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2AB. EXPERIMENTAL STUDIES

10. Form partially coherent images with the Perkin-Elmer enlarger.

    a. Scale up images in spatial frequency by stopping down the transform plane

    b. Study images for which calculations have already been made:

        i. Edges

        ii. Long-line 3-bar targets.

11. Set up an optical bench for partially coherent imaging

    a. Design and construct a liquid gate

    b. Construct and analyze an imaging and collimating system

        i. Measure the incoherent modulation transfer function of the imaging lenses

        ii. Measure the coherence of the collimator by two-pinhole experiments and compare with the results expected from using the Van Cittert-Zernike theorem

    c. Develop a suitable method of maintaining sensitometric control over photographic exposures.

12. Form partially coherent images of amplitude objects on the optical bench:

    a. Edges

    b. Square waves

    c. Long-line 3-bar targets.

13. Fabricate and/or procure more complex targets

    a. Fabricate amplitude sine waves by interferometric techniques combined with linear processing. Analyze them by looking at the orders in the Fourier transform to see if higher orders are present.

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b. Form phase objects by bleaching or etching techniques and analyze phase differences with interferometric techniques

c. Form amplitude and phase objects by partial bleaching of photographic transparencies or by depositing thin metallic layers on a clear substrate.

14. Conduct imaging studies on complex objects:

a. Amplitude sine waves

b. Pure phase objects

c. Amplitude and phase objects.

15. Study partially coherent images formed with polychromatic light and aberrated lenses.

16. Evaluate the results of the quasi-monochromatic imaging studies conducted in item 14 above.

17. Evaluate the results of the polychromatic imaging studies conducted in item 15 above.

18. Compare and assess the results of items 16 and 17 above to determine the conditions under which the polychromatic and quasi-monochromatic representations apply to a particular imaging situation.

19. Compare the final experimental results (item 18) with the final theoretical results (item 19) and assess the overall results of the partially coherent imaging studies.

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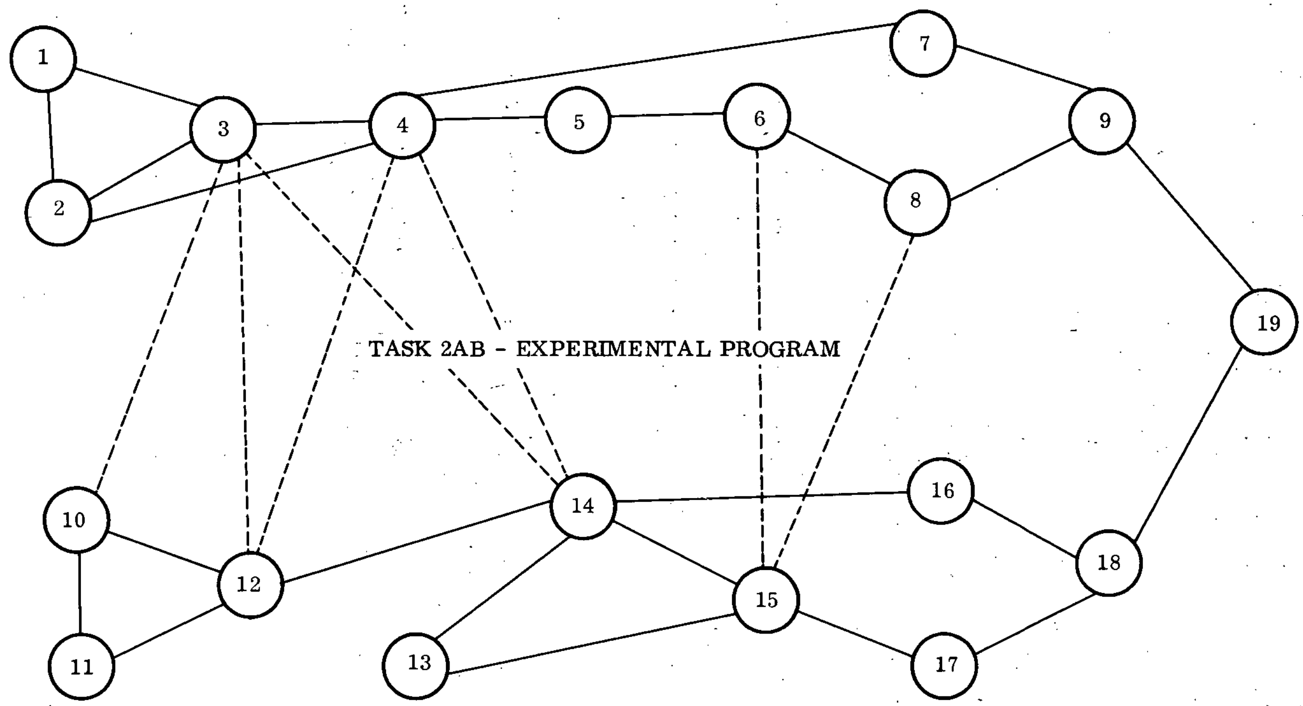
IMAGE ANALYSIS PROGRAM
WORK BREAKDOWN STRUCTURE
TASK 2A. OPTICS
TASK 2AA - THEORETICAL STUDIES



Key:

1. Computer Program for Quasi-Monochromatic Illumination
2. Analytical Solutions
3. Calculate Intensity of Quasi-Monochromatic Illumination
4. Results of Items 2 and 3
5. Computer Program for Polychromatic Illumination
6. Calculate Intensity of Polychromatic Illumination
7. Evaluate Results of Items 2, 3, and 4 for Quasi-Monochromatic Illumination
8. Evaluate Results of Item 6 for Polychromatic Illumination
9. Compare Results of Items 7 and 8 of Task 2AA
10. Images with Perkin Elmer Enlarger
11. Setup Optical Bench for Imaging
12. Images of Amplitude Objects
13. Fabricate and Procure Complex Targets
14. Conduct Imaging Studies on Complex Objects
15. Images with Polychromatic Light
16. Results of Item 14
17. Results of Item 15
18. Results of Task 2AB
19. Results of Task 2A

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IMAGE ANALYSIS PROGRAM
PROGRAM TIME PLAN
TASK 2AA

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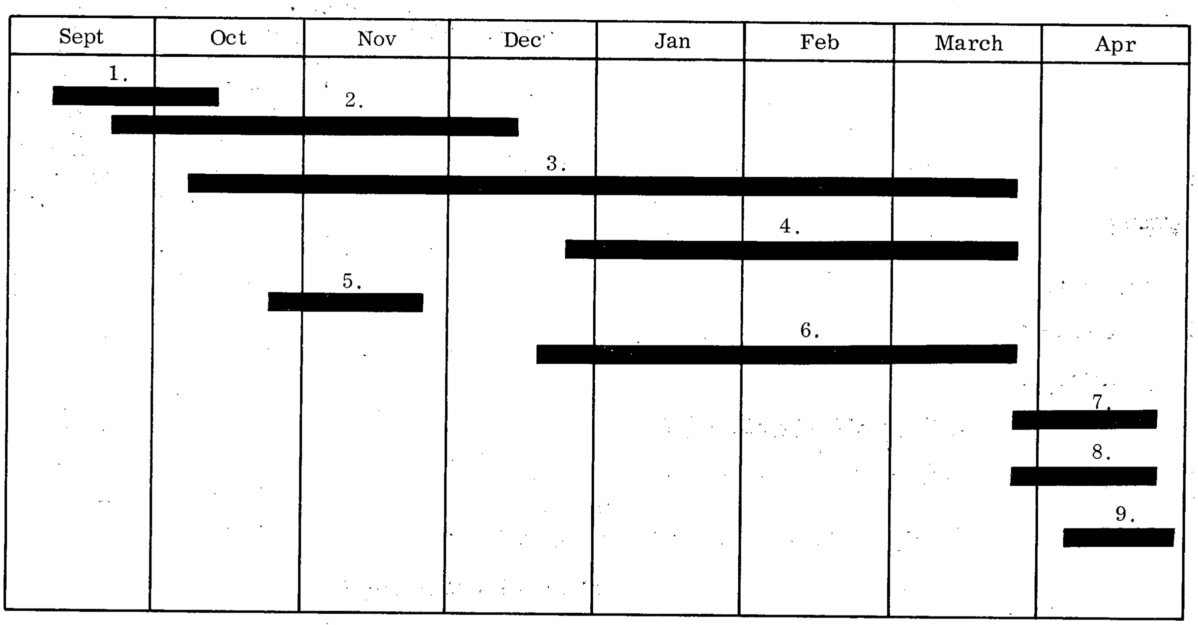

Key:
1. Computer Program for Quasi-Monochromatic Illumination
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3. Calculate Intensity of Quasi-Monochromatic Illumination
4. Results of Items 2 and 3
5. Computer Program for Polychromatic Illumination
6. Calculate Intensity of Polychromatic Illumination
7. Evaluate Results of Items 2, 3, and 4 for Quasi-Monochromatic Illumination
8. Evaluate Results of Item 6 of Polychromatic Illumination
9. Compare Results of Items 7 and 8 of Task 2AA

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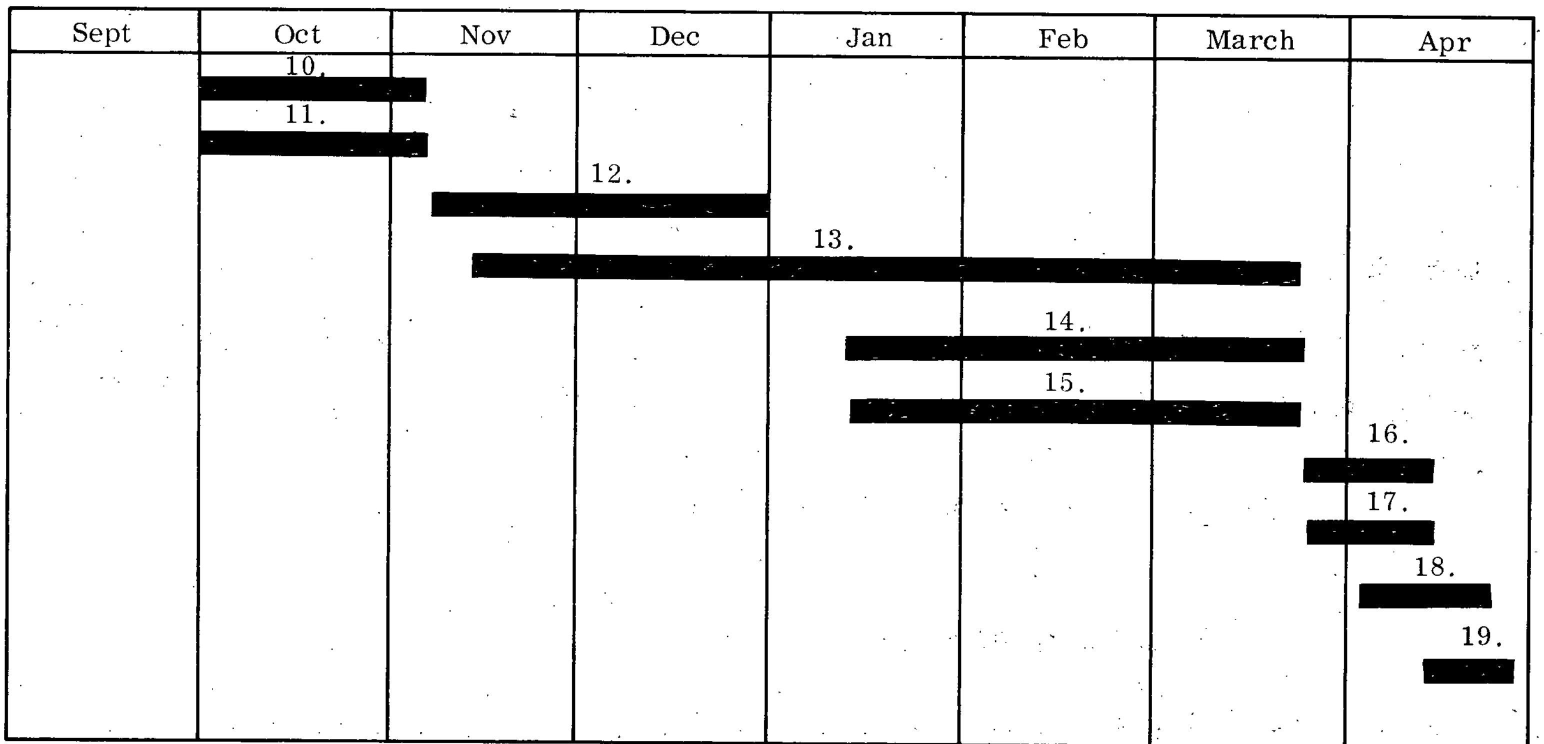
IMAGE ANALYSIS PROGRAM
PROGRAM TIME PLAN
TASK 2AB



Key:

10. Images with Perkin Elmer Enlarger
11. Setup Optical Bench for Imaging
12. Images of Amplitude Objects
13. Fabricate and/or Procure Complex Targets
14. Conduct Imaging Studies on Complex Objects
15. Images with Polychromatic Light
16. Results of Item 14
17. Results of Item 15
18. Results of Task 2AB
19. Results of Task 2A

TASK 2B PHOTOGRAPHY

In the interim 1 October 1966 to 1 April 1967, the Photographic Chemistry Department will perform the experimental program described under Phase I of Task 2B and reiterated in Phase II (Task 5, Experiment). This program will emphasize research in two areas:

1. The fabrication and study of controlled model emulsions

2. The electron microscopy of real and model emulsions.

Model emulsions of known and controllable parameters will be made so that theoretical studies of image quality, to be done primarily by [redacted] 25X1 can be verified experimentally; and, ultimately, so that the relationship between emulsion parameters and image quality can be established.

Electron microscope studies will be made on existing films of interest and on model emulsions. The three principal goals of the electron microscope program will be:

1. To assist in the theoretical studies based on model emulsions

2. To study the relationship between image quality and emulsion parameters

3. To study the relationship between developed filamentary silver in the negative and the image quality of duplicating film exposed in contact with the negative.

WORK PLAN

The work will be divided into three chronological phases:

<u>Phase I: 1 October 1966 to 1 January 1967</u>

1. Prepare model emulsions for [redacted] Supply some 25X1 photomicrograph, grain size distribution (GSD), characteristic curve, and physical parameter data. Engage in bimonthly conferences with [redacted] on the model emulsion program. 25X1 On or about 1 January, evaluate the results of the program and re-evaluate the type of model emulsions needed for the remainder of the program.

2. Study methods for the accurate and rapid determination of emulsion thickness in the sub-5μ range. Study methods for the coating of model emulsions of precise thickness and silver content on a rapid and reproducible laboratory scale.

3. Assemble data on films of interest: SO-132 (3404), 5427, and 8430.

4. Results of items 1, 2, and 3.

Phase II: 1 December 1966 to 1 January 1967 (Overlapping Phase I)

5. Become familiar with the electron microscope and microtome equipment; study methods of replication; try to establish conditions for performing the three types of experiments given in items 6, 7, and 8 below.

6. Measure the thickness of developed silver vs developed density.

7. Determine grain size distribution curve (GSD) of grain emulsions.

8. Study filamentary silver as a function of developed density.

9. Results of items 6, 7, and 8.

Phase III: 1 January 1967 to 1 April 1967

10. Set up precise thickness and laboratory coating equipment for the preparation and measurement of controlled emulsions.

11. Prepare model emulsions in consultation with Diffraction Limited for our own electron microscopy studies.

12. Start the electron microscope studies of films of interest with respect to image quality.

13. Start the electron microscopy analysis of image quality of model emulsions.

DETAILS OF THE PROPOSED PROGRAM

Phase I: Model Emulsions

A model emulsion with which a theory of the characteristic curve can be tested should be monodispersed (have a narrow grain size distribution and a uniformity of grain types) so that the theoretical interpretation of data need not consider dispersion in grain size. The sensitivity of the model emulsion is unimportant within fairly wide limits and nothing more than normal sensitization processes is necessary. However, if any resolution studies are to be made, the emulsion should be low in fog; therefore, we propose that the emulsion be somewhat undersensitized and that generous quantities of antifoggant be used.

In Phase I, the emulsion is to be examined under an optical microscope at [redacted] To insure accuracy the mean grain size must be at least 2μ. 25X1 (5μ would be preferable, however, it is difficult to produce a fog-free emulsion of such a large size. Commercial emulsions rarely exceed the 2μ level and then they are not monodispersed.)

The basic problem of producing a monodispersed emulsion becomes more difficult as the mean grain size increases. The initial grain size immediately after precipitation is probably less than 0.1μ and grows by a mechanism known as Ostwald ripening. The presence of silver complexing agents such as excess halide or ammonia solubilizes some of the silver halide present. The solubility at the surface of the crystal differs from the solubility of the massive phase, the differential depending on the size of the crystal. The local solubility on a small crystal surface is greater than on a large crystal, the origin of the phenomenon being a function of the surface potentials. The net effect is that as ripening proceeds, a small crystal is slowly dissolved and the material is reprecipitated on the surfaces of larger crystals (in effect, the large crystals grow at the expense of the small ones). Crystal growth, then, depends on a lack of monodispersity. The differential in solubility decreases rapidly as the size of the smallest crystal increases, for example, a 0.2μ grain "feeding" on a 0.1μ grain would occur much more readily than a 2μ grain "feeding" on a 1μ grain.

The preceding discussion has attempted to show that a "monodispersed" emulsion made by the Ostwald ripening procedure cannot ever be truly monodispersed. We can only attempt to minimize the dispersion as much as possible. Moreover, the larger the required grain size,the more difficult minimization becomes. Grains can be fractionated by sedimentation, but it is difficult to produce reasonable quantities of emulsion grains in this way; however, the procedure may be necessary later in the program.

Approach

Two types of grains can be grown: octahedral and cubic. The octahedral type is formed in predominantly bromide complex $(AgBr_4)^{-3}$ conditions and appears as the well-known triangular platelets. The cubic type is produced under predominantly ammoniacal conditions $(Ag(NH_3))_2^+$. Theoretically, these should appear as cubes, but corners are usually etched off, producing vaguely spherical shapes. This second type is preferred for theoretical models for two reasons:

a. It is spherically symmetrical.

b. It is more likely to approach monodispersity, probably due to the fact that it grows in three dimensions (rather than the two dimensions in an octahedral system). Ammonia is therefore the intended complexing or ripening agent on this program.

We shall now discuss the first three steps of Phase I:

1. Prepare the Model Emulsion

In Phase I, our target will be a 2μ monodispersed emulsion in which no special techniques beyond Ostwald ripening need be employed to increase grain size. The research will concern monodispersity accomplished by systematic change of complexing agent concentration and jetting time with constant microscopic monitoring throughout the ripening period. Such an emulsion is to be formulated and presented to [redacted] before 1 November, and we hope that the formulation can be modified as talks with that company proceed. 25X1

Having established the methods for preparing a monodispersed emulsion for the 2μ range, we may then accomplish additional grain growth by adding a

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stock of very fine grains after the first ripening period. This will allow the 2μ grain to "feed on" small grains. Should the 2μ grain size still be insufficiently large for microscope observation, subsequent feedstock can be added as necessary. The difference in volume between a $5\mu^3$ grain and a $2\mu^3$ grain is $125/8 = 15{:}1$; this implies that for any given amount of silver, only 7.3% produces the 2μ grains and 92.7% acts as feedstock. An emulsion of 5μ grain size should be available by 1 December.

One hazard commonly found in making highly ammoniacal emulsions is the presence of fog, which comes about because of the tendency of $Ag(NH_3)_2^+$ to be reduced in the presence of gelatin at high pH. One means of avoiding this is to use ammonium salts rather than alkali metal salts. In the presence of ammonia, the ammonium ion acts as a buffer and depresses the pH, making the degradation of gelatin less likely. For this reason, we will use ammonium salts of the halide in our emulsion preparation.

Our emulsions will be sensitized by the controlled deposition of silver sulphide from sodium thiosulphate at an elevated temperature. We must point out here that even in a monodispersed emulsion, the sensitization process will change the speed of some grains more than others by a statistical process so that there will always be a distribution in grain sensitivity if not in grain size. This is true even of the basic sensitivity of the monodispersed emulsion because of the statistical distribution of defects within the grains. After precipitation and ripening, the emulsion will be diluted with gelatin solution and coated under differing conditions. Prior to submission of emulsion samples to [redacted] photomicrographs and H and D curves of the emulsion will be prepared; thickness determinations and silver analyses will be made as needed. 25X1

To assure a continuous understanding of the emulsion requirements, we propose to hold regular semimonthly meetings between [redacted] until 1 January 1967. Mutually acceptable definitions of such topics as "monodispersity" and "sensitivity" will hopefully result from such meetings. 25X1 25X1

2. Determine Methods of Coating and Thickness

We plan to study the various analytical methods of silver analysis so that we can set up the one most suitable for our specific problems. At present, we use a

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titration method that is not sufficiently rapid for the needs of this program. Of the new methods considered, the potentiometric end-point method and the dye indicator method seem most favorable.

Methods of measuring the coated thickness of an emulsion coating will also be studied. We use a mechanical measurement device at present, but this is not rapid enough for the needs of the program. An air gauge method may prove suitable. The program requires us to make high quality coatings in rapid order, with controlled variations in coating weight. For this reason, a study of the various small controllable coating systems will be made and will include injection, kiss, dip, and doctor blade coating systems.

3. Assemble Data on Films of Interest

Characteristic curve, resolution, and silver coverage data on SO-132, 5424, and 8430 will be gathered from [redacted] files and by taking further data as needed. 25X1

Phase II: 1 December 1966 to 1 January 1967 - Electron Microscope Studies

We expect the electron microscope to be installed in our laboratory during November. During December, we hope to establish the basic techniques for electron microscope observation of photographic film. In particular, we hope to establish experimental methods in three areas:

1. The measurement of the thickness of the developed image as a function of the developed density. We know that at lower density the developed silver lies near the emulsion surface, while at higher density the silver appears throughout the thickness of the emulsion. This should lead to differences in image quality as a function of density. We would like to observe these thicknesses in the electron microscope under low magnification. This may require careful microtoming of the emulsion in cross-section, and the replication of such samples may prove to be a challenge.

2. The determination of the grain size distribution curves for fine grain emulsions. In Phase I of the proposed program, large grained model emulsions will be used to allow for optical microscope grain counting. In emulsions of interest, the grains are small and must be observed by the electron microscope. In later studies, we hope to determine the relationship between grain shape and size distribution, and image quality, which will require constant measurement of the grain size distribution by the electron microscope.

3. The study of the structure of developed filamentary silver. In the original negative, the nature of the developed silver is a function of both the emulsion and the processing conditions. When the developed negative acts as a mask for exposure of the duplicating film, the nature of the developed silver in the negative may influence the quality of the image on the duplicating film.

<u>Phase III: January to April 1967</u>

1. Studies on thickness measurement devices and laboratory coaters made during Phase I will be brought to fruition by the installation or construction of such instruments in our laboratory.

2. Model emulsion-making will continue, based on the results of the research and conferences prepared in Phase I and on the degree of sophistication of electron microscopy to be accomplished in Phase II. In Phase I, large-grained emulsions will be needed to allow for rapid optical observation of the grains. In Phase IV, fine-grained emulsions of different crystal class and grain size may be required, providing they can be observed with the electron microscope on a routine basis. Independent of the theoretical work of [redacted] our electron microscope program will require the fabrication of model emulsions for the study of image quality. 25X1

3. The electron microscope program of Phase III will be determined largely by the experimental results of Phases I and II. As an overall goal, we will study the relationship between emulsion parameters and image quality on the original negative and the relationship between the developed image of the negative and its effect on the image quality of the duplicating film.

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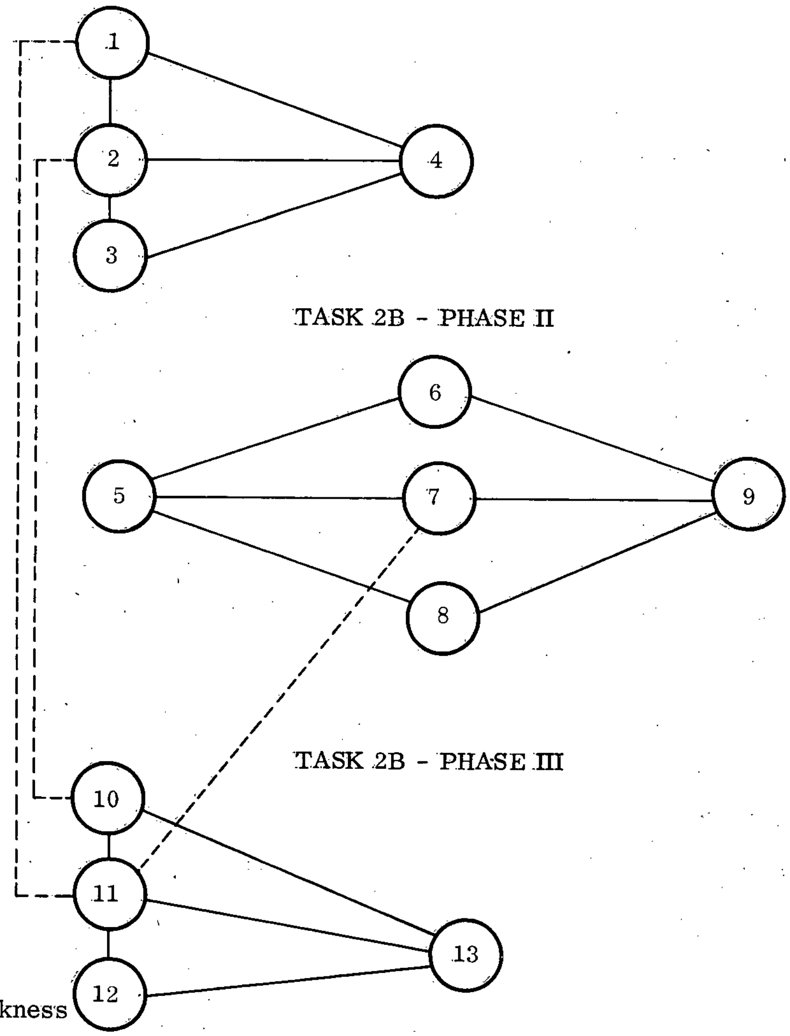
IMAGE ANALYSIS PROGRAM
WORK BREAKDOWN STRUCTURE
TASK 2B - PHASE I



Key:

1. Model Emulsions
2. Study Emulsion Thickness
3. Film Data
4. Results of Items 1, 2, and 3
5. Familiarization with Electron Microscope
6. Measurement of Silver Thickness
7. Grain Size Distribution
8. Filamentary Silver
9. Results of Items 6, 7, and 8
10. Construct Thickness and Coating Equipment
11. Prepare Model Emulsions
12. Film Studies by Electron Microscope
13. Analysis of Emulsions by Electron Microscope

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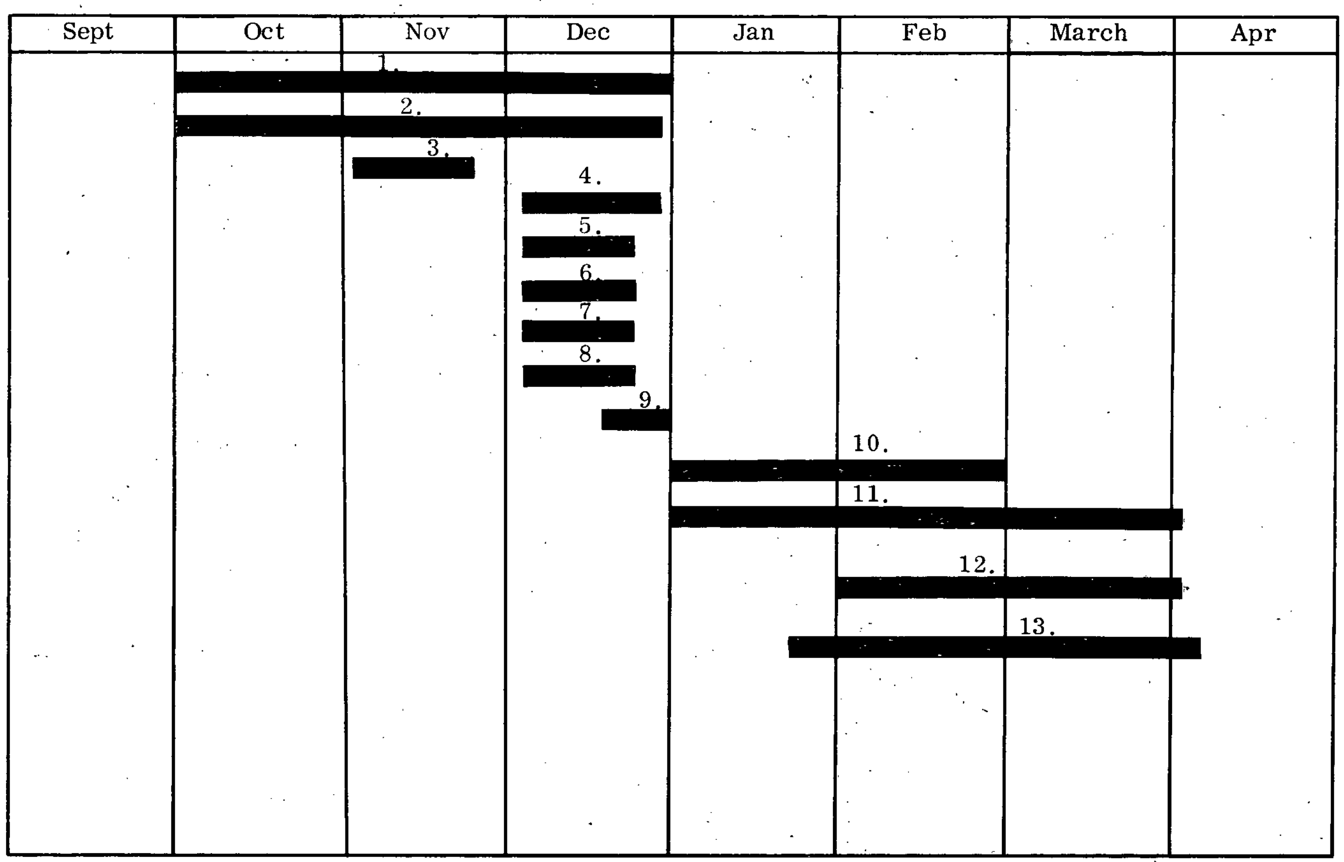
IMAGE ANALYSIS PROGRAM
PROGRAM TIME PLAN
TASK 2B



Key:
1. Model Emulsions
2. Study Emulsion Thickness
3. Film Data
4. Results of Items 1, 2, and 3
5. Familiarization with Electron Microscope
6. Measurement of Silver Thickness
7. Grain Size Distribution
8. Filamentary Silver
9. Results of Items 6, 7, and 8
10. Construct Thickness and Coating Equipment
11. Prepare Model Emulsions
12. Film Studies by Electron Microscope
13. Analysis of Emulsions by Electron Microscope

TASK 2C PHOTOMETRICS

The program described here is designed to determine the extent to which two basic assumptions made in microdensitometric image evaluation work are justified. These assumptions are (1) that the illumination in the preslit of a microdensitometer may be regarded as incoherent and (2) that the scanning spot illumination in the object (or film) plane of a microdensitometer may be regarded as incoherent. We shall investigate these two basic assumptions both theoretically and experimentally according to the following plan. We shall:

1. Write the program for the IBM 360 computer, which will calculate the mutual intensity in the image of a partially coherent quasi-monochromatic source of arbitrary mutual intensity. We shall write this program assuming an ideal diffraction-limited lens.

2. Measure experimentally the mutual intensity distribution in the plane of the Joyce-Loebl (hereafter referred to as J-L) microdensitometer preslit using a two-pinhole interferometer. This tests the assumption that the preslit is incoherently illuminated.

3. Use the computer program written under item 1 of this task to calculate the mutual intensity distribution in the object (or film) plane of the J-L microdensitometer, assuming that the preslit is incoherently illuminated.

4. Use the computer program written under item 1 of this task to calculate the mutual intensity distribution in the object (or film) plane with the mutual intensity distribution of the preslit plane measured in item 2.

5. Compare the results of items 3 and 4 to determine the validity of the assumption that the object (or film) plane of the J-L microdensitometer is incoherently illuminated and the extent to which coherence in the object plane is affected by the coherence in the preslit plane. Generalize these results, if practicable, to microdensitometers other than the J-L and verify, if possible, the conclusion for at least one other instrument.

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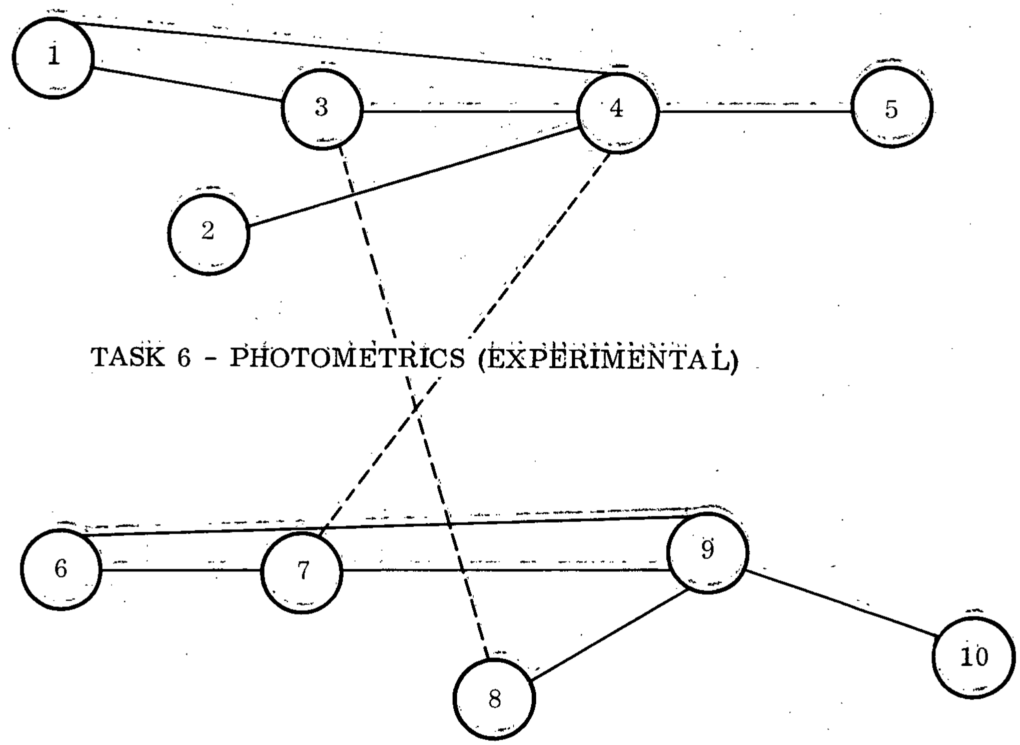
IMAGE ANALYSIS PROGRAM
WORK BREAKDOWN STRUCTURE

TASK 2C - PHOTOMETRICS (THEORETICAL)

TASK 6 - PHOTOMETRICS (EXPERIMENTAL)



Key:
1. Computer Program
2. Experiment with Preslit
3. Calculate Intensity with Object
4. Calculate Intensity with Fixed Preslit
5. Compare Results of Items 3 and 4
6. Calculate Image Intensity
7. Calculate with Results of Item 4
8. Calculate with Results of Item 3
9. Compare and Evaluate Results of 6, 7, and 8
10. Examine Findings

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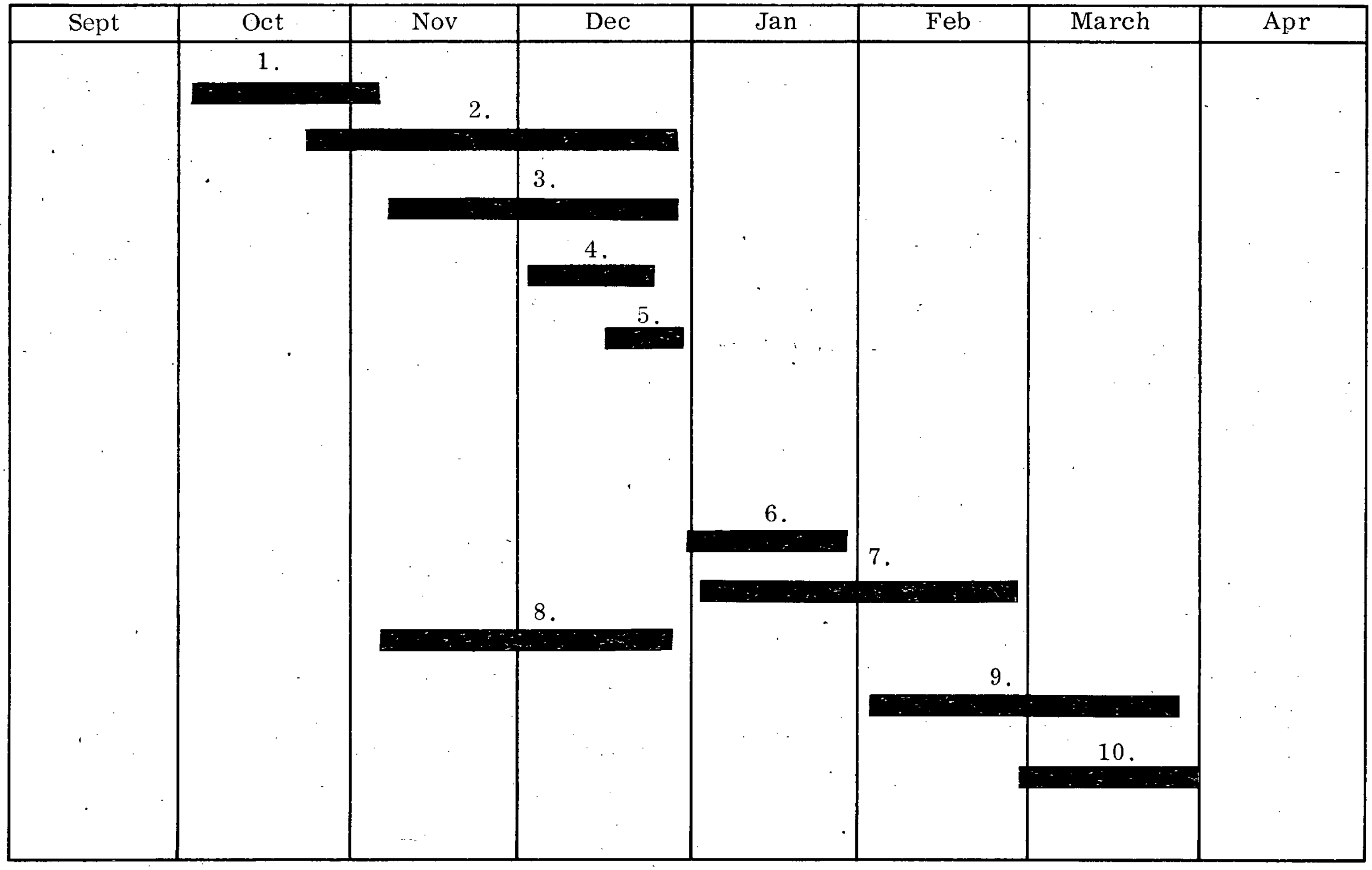
IMAGE ANALYSIS PROGRAM
PROGRAM TIME PLAN
TASK 2C



Key:
1. Computer Program
2. Experiment with Preslit
3. Calculate Intensity with Object
4. Calculate Intensity with Fixed Preslit
5. Compare Results of Items 3 and 4
6. Calculate Image Intensity
7. Calculate with Results of Item 4
8. Calculate with Results of Item 3
9. Compare and Evaluate Results of Items 6, 7, and 8
10. Examine Findings

TASK 6 PHOTOMETRICS

The program proposed under this task is designed to determine the effects of conclusions reached in Task 2C on the imaging of certain test objects commonly used in image evaluation. We shall:

6. Use the computer programs written under Tasks 2A and 2C to calculate the image intensity distribution for ideal lenses and quasi-monochromatic incoherent illumination using the following objects:

a. Sine waves

b. Edges

c. Square waves

d. Three-bar targets.

Since the illumination is incoherent, these objects will be studied as pure amplitude variations.

7. Use the results of item 4 of Task 2C for the illumination mutual intensity to calculate the image intensity distribution, assuming an ideal imaging lens. The illumination will be, in general, partially coherent and quasi-monochromatic. Again, the objects will be those enumerated in item 1 of Task 6 and will be studied as pure amplitude variations.

8. Use the results of item 3 of Task 2C to calculate the image intensity for the group of objects enumerated in item 1 of Task 6 — the only difference will be in the mutual intensity of the object illumination as found in item 3 of Task 2C.

9. Compare and evaluate the results of items 1, 2, and 3 of Task 6 to determine the effect of the coherence determined in Task 2C on the imaging of these test objects.

10. Examine the optical illumination systems of those microdensitometers commonly used in evaluation of high quality photographic material to determine what differences exist and, if any, what further studies might be necessary to apply the type of analysis employed here to those systems.

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FINANCIAL DATA

FOR

IMAGE ANALYSIS RESEARCH

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SUBCONTRACTORS

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PLANNED PROGRAM

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October 1966 through April 1967

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TASK 7

TASK 7-1

Image restoration programs currently being done by [redacted] 25X1
[redacted] are expected to contribute to this program next year. The optical systems needed require special properties normally not needed in lenses. For example, lenses in general are corrected for one position of the object and consequently for one magnification; however, for the systems under consideration, two imaging planes are needed to perform the necessary filtering. 25X1

The imagery in both planes has to have good image quality to perform the task satisfactorily. There are theoretical difficulties in optically correcting two planes for aberrations simultaneously. The tendency in optical design is to add more components to the system when better imagery is desired. Here, however, it is important to minimize the number of components since every additional element will have some surface defects (such as dust particles), which will materially degrade the results obtained. It therefore becomes important that the number of elements be kept to a minimum.

We propose to investigate the basic limitations imposed by the laws of optics on imagery in two planes simultaneously and use the best way to minimize the number of elements in such a design.

TASK 7-2

The grain of a photographic emulsion will have a profound influence on the images formed by these emulsions. [redacted] has done theoretical work 25X1
on the statistical imaging properties of such films. The experimental verification of the derived results is very difficult since all commercial films have relatively small grain sizes and are composed of many layers of grains.

The basic measurements, in the beginning, should be made with a photographic emulsion having as large a grain size as possible. [redacted] is therefore preparing 25X1
large-grained emulsions to be used in these experiments, which will enable us to measure the properties of the emulsion with the least amount of ambiguity. Furthermore, the emulsions will have a simple layer of grains, which will dispense with

[redacted] 25X1

the problem of scattering and overlapping of the grains of the model and allow us to verify the basic assumptions of the statistical model. The time plan is as follows:

1. In the first phase, we shall measure the granularity and grain size distributions of these emulsions for different densities.

2. After verifications of the theory, we shall print simple patterns on the emulsions to compare the resulting images with the predicted results. From the study of these samples, we hope to improve our model, coming closer and closer to the materials in actual use by measuring the predicted results with the actual results. This effort will produce a better method of predicting the expected image quality of a lens film combination and will give the basic understanding needed to improve the viewing techniques used with these images for interpretation purposes.

TASK 7-3

The quality and imaging properties of viewing equipment pose a difficult problem. With the sine wave test equipment that is presently being built, we can measure the sine wave transfer function of a viewer alone and then the sine wave transfer function of the equipment including the "operator." We deliberately use the word "operator" instead of photointerpreter to stress the fact that we have eliminated the psychological and interpretational aspects of the problem. We do have an objective method, however, to investigate whether there is a difference in the inherent capabilities of various instruments and their design.

3. In cooperation with the contractor, we shall investigate some of the results obtained from actual instruments and try to formulate instrumentation requirements to maximize the performance of viewing systems in conjunction with the operator. This program will consist of two phases.

4. Measure the various response functions for existing equipment, both for the equipment alone and for the system consisting of the equipment including the operator.

5. Try to explain the results obtained in the first phase and formulate requirements for future instruments.

TASK 7-4

6. All existing programs to compute the transfer function of a lens with residual aberrations are based on the premise that the objects are incoherently illuminated. This, however, is not the case in viewing equipment, and virtually nothing is known about imagery with partial coherent objects if the lens has aberrations (as all actual lenses do). It becomes extremely important to know the imaging properties of lenses in the case of partial coherent illumination. In conjunction with which has done work in the area of partial coherent imagery for the "perfect" lens system, we will extend this work to include actual lenses with residual aberrations. This will result in computer programs that will allow the evaluation of various lens designs in conjunction with the proposed illumination system. Without such programs, it is impossible to evaluate whether a lens design is adequate to perform the tasks it is intended for.

TASK 7-5

All studies of the effect of temperature variations on the image quality of a lens system evaluate the expected results and corrective measures to be taken when the operating temperature of the lens is changed from temperature 1 to temperature 2. All conclusions are based on the assumption that the whole system is again in temperature equilibrium at temperature 2. In actual operating conditions this is usually not the case. The ambient temperature is constantly changing, and therefore the optical system is generally in the process of changing. The effect of temperature changes are manifold:

a. The index of refraction of the lens material changes. If the elements have temperature gradients, one has, in effect, a lens of varying refractive index.

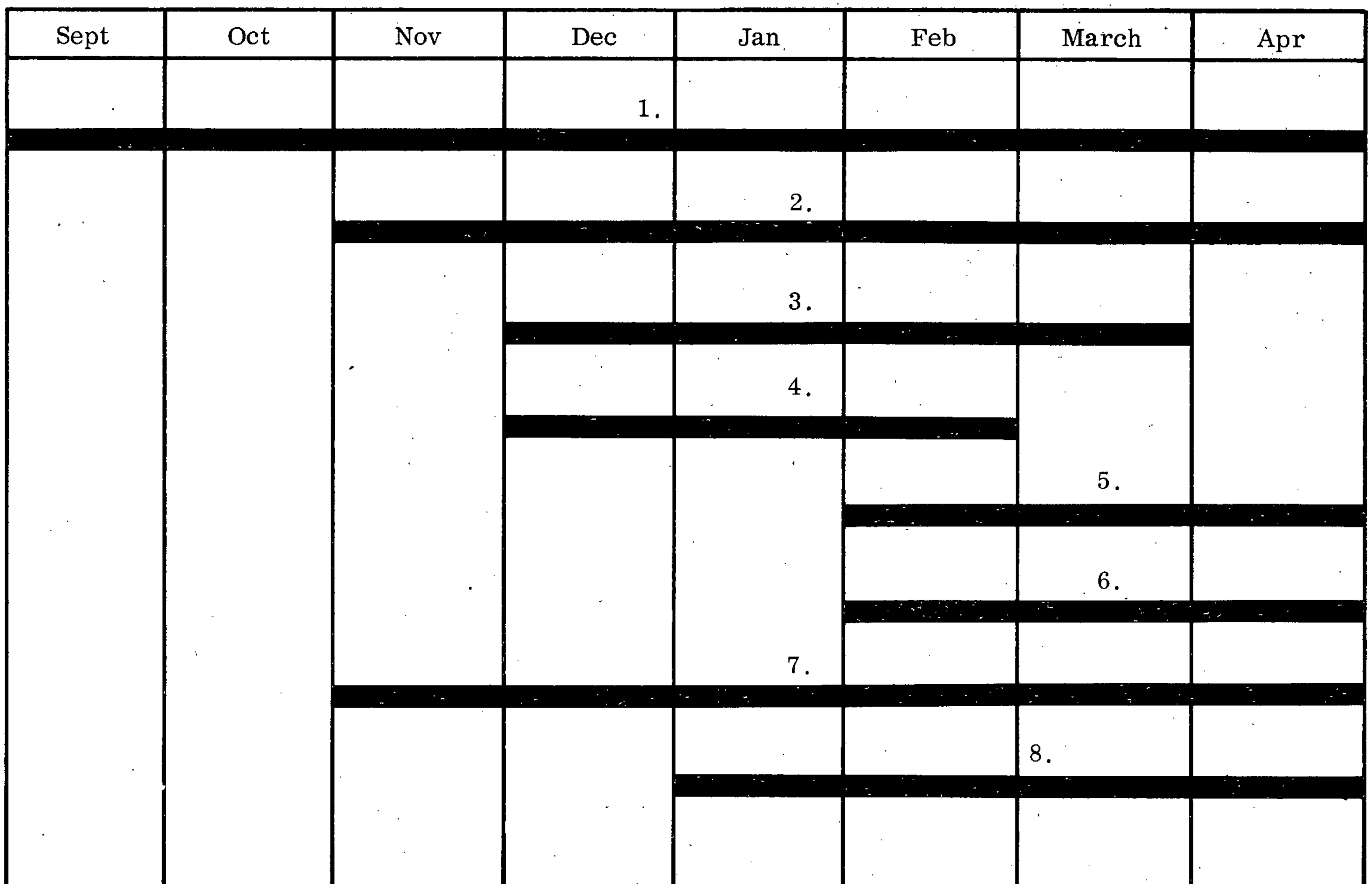
b. The lens expands, and if temperature gradients are existant, this introduces strain in the optical element. This, in turn, makes the lens birefringent, and different polarization directions of the light forming the image encounter different refractive indices in the same area of the lens element. Imaging properties for lenses under these conditions are totally unknown. Virtually the only thing known is that even slight temperature gradients have disastrous effects on the image quality. There are two avenues of investigation:

7. Investigate the image quality obtained during a long run of many temperature cycles by edge analysis of the imagery obtained (the question of the precise interpretation of these measurements is unimportant here since deterioration of the image quality is detectable by this method) and look for correlations between these results and the known outside temperature cycles. No efforts have been made to evaluate the deteriorating effects in present systems, although this can be done. Since the systems are subjected to a cyclic temperature variation, it is likely that the image deteriorations due to this have a cyclic nature. There will be a phase shift between the two time cycles. We believe that some systems are much more sensitive to these effects than others and it would be useful to do this investigation for two camera systems with different optical arrangements.

8. We can come to some conclusions concerning the magnitude of the effect as a function of the element powers used in the system and the types of glass used, although detailed investigation of these phenomena will be too complicated to attack at this stage.

We therefore propose to investigate the basic effect of different materials and different configurations in order to evaluate the difference designs and put them in order as to the expected image deteriorations.

IMAGE ANALYSIS PROGRAM
PROGRAM TIME PLAN
TASK 7



1. Experimentation to Verify Theoretical Results
2. Measuring of Photographic Samples
3. Study Phase
4. Measuring Response Functions
5. Explaining Results
6. Write Computer Programs
7. Measuring Edge Functions
8. Theoretical Program

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PLANNED PROGRAM

FOR

IMAGE ANALYSIS RESEARCH

October 1966 through April 1967

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TASK 8

8A. TECHNICAL PROGRAM

The proposed program for the remaining six months is divided into four task areas: (1) continuation of evaluation of effective exposure, (2) study of film transfer functions, (3) study of mensuration capability of duplicating film, and (4) support as required by [redacted] The proposed outline for each of these task areas is given below. 25X1

1. <u>Continuation of Effective Exposure Investigation</u>

In view of the great emphasis placed upon this idea in image quality measurements, the experiment will be run again using 3400 and 8430 films. The experiment will also be run again with 3404 film utilizing sensitometric processing, and the data will be compared with that obtained previously to see whether the processing conditions are an important factor in effective exposure. We can obtain the data easily merely by making the required exposures, since the complete experimental set-up is available.

These data should be a valuable aid in the development of mathematical models of film response that are better than the effective exposure concept. By using more than one film, we can develop a more generalized model.

2. <u>Measurement of Film Transfer Functions</u>

The concept of transfer functions for film is ill-defined because of the present methods of placing controlled aerial images on film and the amount of modulation used in generating the test material. Since the modulation transfer function is used as an important figure of merit in the evaluation of emulsions, several questions should be answered: (1) Does the modulation transfer function remain constant with variations in input modulation or, in other words, are the large-scale and small-scale transfer functions the same? (2) Does the small-scale transfer function vary with changes in average density level? (3) Does the average exposure change as line frequency varies and modulation remains constant?

The proposed task area includes work on three films — 3404, 8430, and SO-233. Two wavelengths of light will be used in making test exposures. With minor changes, the present test set-up can be used to generate aerial image sine waves with accurately measured modulations and intensity levels. The results of effort on this task should provide important data for use in the image restoration work now being done and should aid in development of more realistic criteria for the evaluation of emulsions. In addition, this work will establish techniques to be proposed as standard for image quality program efforts to follow.

3. <u>Mensuration Properties</u>

The ability to extract data from photography is a function of dimensional stability, image quality, and other factors. In many instances, the photo-interpreters and photogrammetrists involved are dealing with prints of varying generation and varying image quality rather than with the original. It is important to establish the quality of photogrammetric data as a function of generation for enough cases that some confidence in results may be obtained. In order to be meaningful, these measurements must be referenced to known high accuracy primary data. The duplication will be made onto both 8430 and SO-233 with 3404 to be the taking material.

The objectives are:

a. To analyze error propagation through four generations

b. To compare results with equipment capabilities

c. To evaluate equipment requirements.

To conduct the experiment in a simple fashion with maximum emphasis on the basic problem, two-dimensional objects will be utilized. The experimental program will include objects of such size that a progression of measurements will include those both removed from and near the resolution limit. The program contemplated will, in fact, be a team effort among the three companies involved. [redacted] 25X1
[redacted] will supply a lens (Schnieder F3.5 copy lens) to [redacted] for focal 25X1
length and MTF calibration on axis. Photographs will be taken and film reproduced at [redacted] where mechanical measurements of object size will be made 25X1
by

1. Comparator (cross-hairs)

2. Microanalyzer (spot).

[redacted] 25X1

The photographs will then be supplied to [redacted] for edge differentiation and 25X1
subsequent analyses will be made jointly by [redacted] 25X1

Simultaneously, a request will be made through appropriate channels for the activation of a limited CORN edge measurement experiment by Processing Center's personnel. The objective of this experiment will be the determination of two-dimensional error propagation parameters through the standard duplication system. Appropriate procedures will be written and supplied, and data reduction support will be provided as required.

This problem is of more than academic interest. More than 50% of typical photo-intelligence output involves measurement. Experiments of this nature have been proposed, but apparently little has actually been accomplished in this regard. It is also probable that mensuration accuracy may be a useful key to the effect of varying image quality. Furthermore, such tests may be essential in the assessment of subsequent generation material.

4. <u>General Support</u>

Support will be provided for other areas of the program as required by [redacted] 25X1
including both the analytical and experimental areas, as well as support required in establishing requirements for the Processing Center's mensuration program.

8B. TECHNICAL MANAGEMENT AND PLANNING

An allowance must also be made for a certain number of hours to be devoted to technical management and planning. This item will include such activities as technical coordination, joint activity with the prime contractor such as compliance with major reporting requirements, technical review, and analytical activities.

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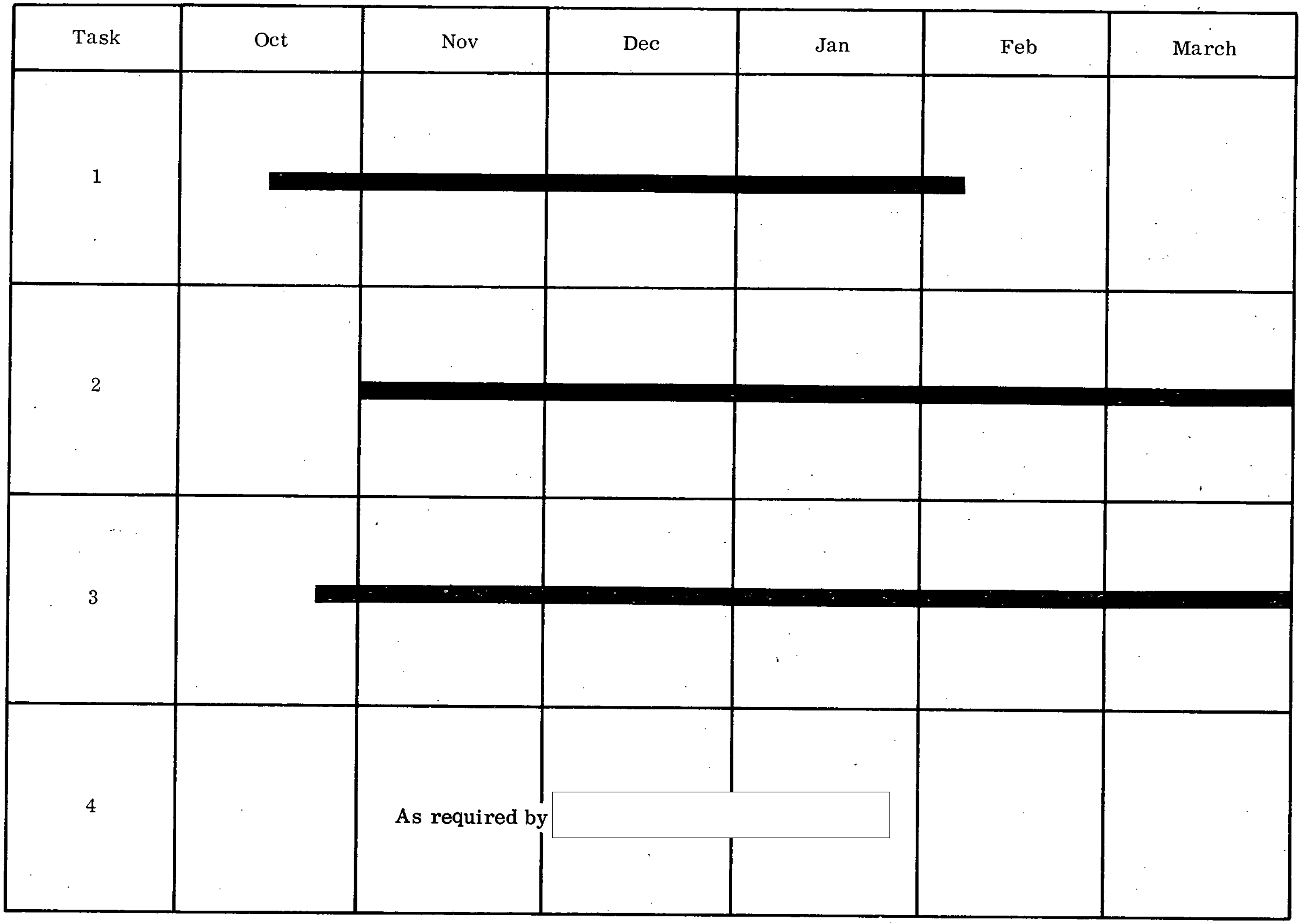
IMAGE ANALYSIS PROGRAM
PROGRAM TIME PLAN
TASK 8



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